Mechanical Harvesting of Wine Grapes

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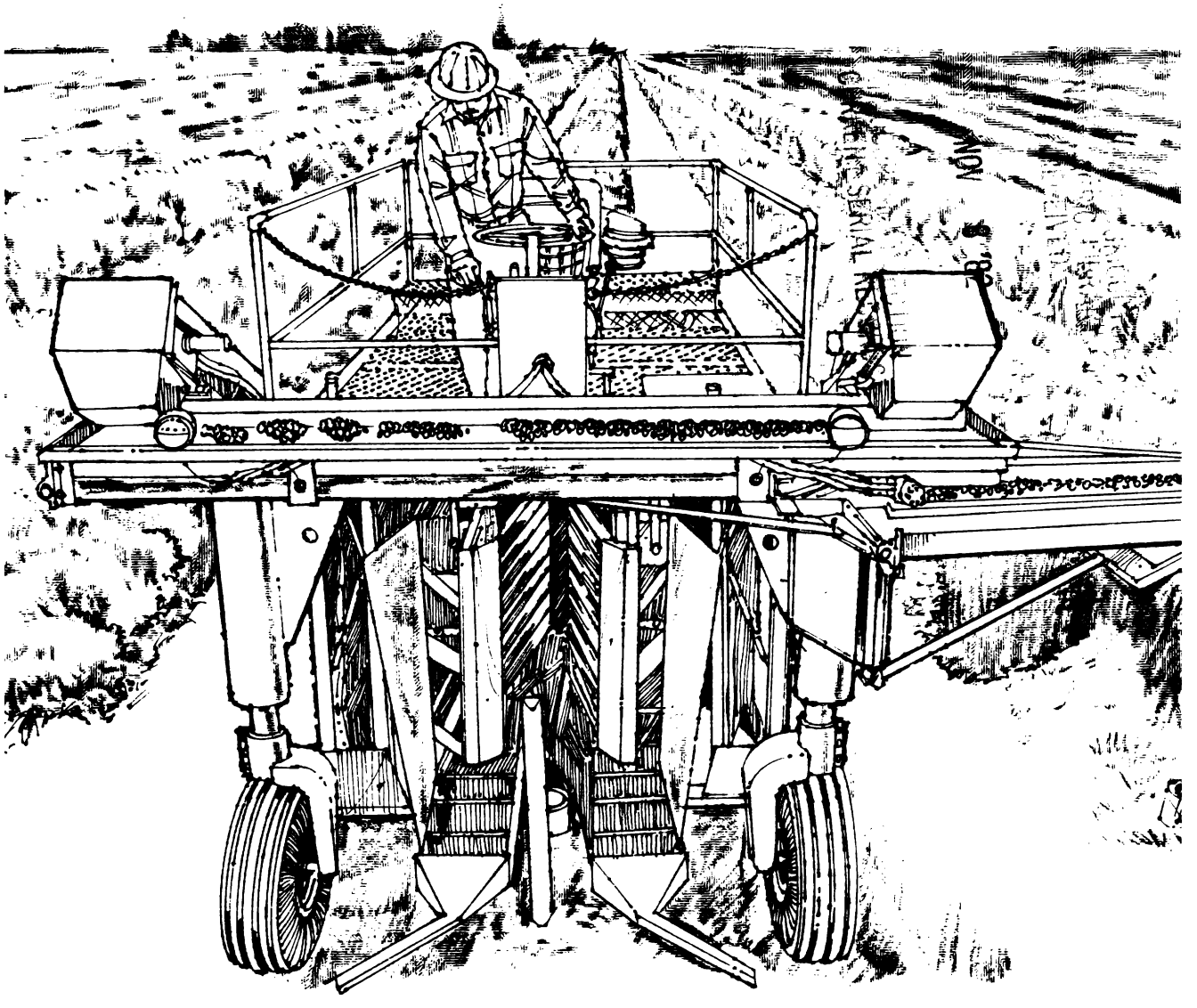

MECHANICAL HARVESTING OF WINE GRAPES. By Stanley S. Johnson, Commodity Economics Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 385.

ABSTRACT

Mechanization of the California wine grape harvest has slowed, with no rapid increase expected for the immediate future. However, a lot depends on solving current problems of wine quality using mechanically harvested grapes and machine damage to vines as well as generally low grape prices and the labor situation.

The study points out that mechanical harvesting is only economical on larger acreages. For example, at an 8-ton-per-acre yield in 1972, a farm would have to be 220 acres in size in order for mechanical harvesting costs to break even with those of hand harvesting. On the other hand, if farmworker wages went up by a fourth or more over other costs, machine harvesting could increase the competitive edge.

In general, owners of mechanical harvesters viewed their machines favorably, most often noting that they liked the increased control over their operations and the relative freedom from labor problems. Operational problems cited were vine and stake damage and juicing of the grapes.

Keywords: Harvesting, grapes, labor, mechanization.

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SUMMARY

A mechanical harvester was introduced to California's vineyards in 1969, and by 1974, between 5 and 10 percent of the wine grape crush was being mechanically harvested. Machine adoption has slowed, however, and no rapid increase is indicated for the immediate future. Just exactly what the future holds for mechanization of the grape harvest will depend on solving current problems of wine quality using mechanically harvested grapes and machine damage to vines as well as on grape prices and cost and availability of labor.

To compare machine harvesting economics with those of hand harvesting, a survey was conducted in the San Joaquin Valley prior to the 1973 grape harvest. Owners of mechanical harvesters and those employing hand harvesting crews were interviewed.

Results show that machine use in 1972 averaged 237 acres, principally in a single shift of 10.3 operating hours per day, at an average harvest rate of 0.7 acre per hour. Half of the machine owners did custom harvesting, largely basing their charges on contract rates for hand harvesting.

Owners indicated that the principal advantage of the machine was that it helped to free them from labor problems, allowing more control over their operation. Operational problems included vine and stake damage and juicing of the grapes. Overall, however, the machine owners viewed their machines favorably.

Production costs were calculated for Thompson seedless grapes in the San Joaquin Valley. Farms were grouped into a range of farm size from 40 to 240 acres, and costs were calculated on the basis of an average yield of 8 tons per acre using hand harvesting. Total production costs using hand harvesting ranged from $758.55 to $689.59 per acre over the several farm sizes, and from $925.91 to $687.40 over the same size range using machines for harvesting. At a farm price of $75 per ton, the net returns to management and operator's labor indicated financial losses at the 8-ton yield regardless of farm size or harvesting system. At 10 tons per acre, the larger farms had positive net returns. If wages of farmworkers were to rise by 25 percent relative to other costs, the high proportion of labor in hand systems would increase the competitive advantage of machine harvesting.

The point at which machine harvesting costs broke even with those of hand harvesting varied by farm size and yield. The higher level of fixed costs made machine harvesting systems more costly per acre than hand systems on smaller farms. The break-even point at the 8-ton yield was reached at a farm size of 220 acres. At yields of 7 to 10 tons per acre, machine break-even acreages ranged from 140 to over 240 acres.

The labor requirements of machine harvesting are only 19 percent of those for hand harvesting. The 5 to 10 percent grape-harvest mechanization in the southern San Joaquin Valley is estimated to have reduced jobs by 4 to 8 percent.

In the study, the investment of $45,200 in the mechanical harvester and two gondolas substituted for 6,000 hours of labor on a 240-acre farm. Therefore, every $7.53 invested in machines substituted for 1 hour of labor.

MECHANICAL HARVESTING OF WINE GRAPES

by
Stanley S. Johnson 1/

INTRODUCTION

The wine grape industry is in a period of rapid change. Increased consumption of wine in the late sixties and early seventies boosted prices for wine grapes, encouraged wine production, and led to greatly increased plantings of grapes. When the increase in consumption slowed in 1973 and 1974, an oversupply of wine grapes resulted, with consequent low prices to grape growers.

The wine grape grower has few alternatives while waiting for demand and supply to balance. Rapid adjustments of supply are difficult for perennial crops such as grapes, which require 3 years to come into production. However, one alternative for growers of a multipurpose grape variety, such as Thompson seedless, is the raisin market. Another partial solution is to remove vines to make way for an alternative crop. A third alternative, the subject of this study, is to mechanize the grape harvest to reduce costs. To study the effects of mechanization on financial returns to growers, data from a 1973 survey were used to determine the characteristics of theoretical farms. Costs were calculated for 1975.

The mechanical harvester has been in commercial use in California since 1969, harvesting grapes for wine. The number of machines in the State increased from 59 in 1970 (7) to 103 in 1972. 2/ The 1974 number is estimated at 200 or more, with a conservative estimate of mechanically harvested grape tonnage of 5.6 percent of the State's winery crush. 3/

Objectives and Procedures

This study was made (1) to provide information on mechanization of the grape harvest in California, (2) to provide growers and others with comparative costs of hand and machine operations for making informed decisions in adjusting to a changing technology and market, and (3) to analyze the effects on growers and workers of substituting machinery for labor. Only wine grape mechanization was examined, although the potential exists to mechanize the raisin harvest.

Grape Harvest Season and Employment, Southern San Joaquin Valley

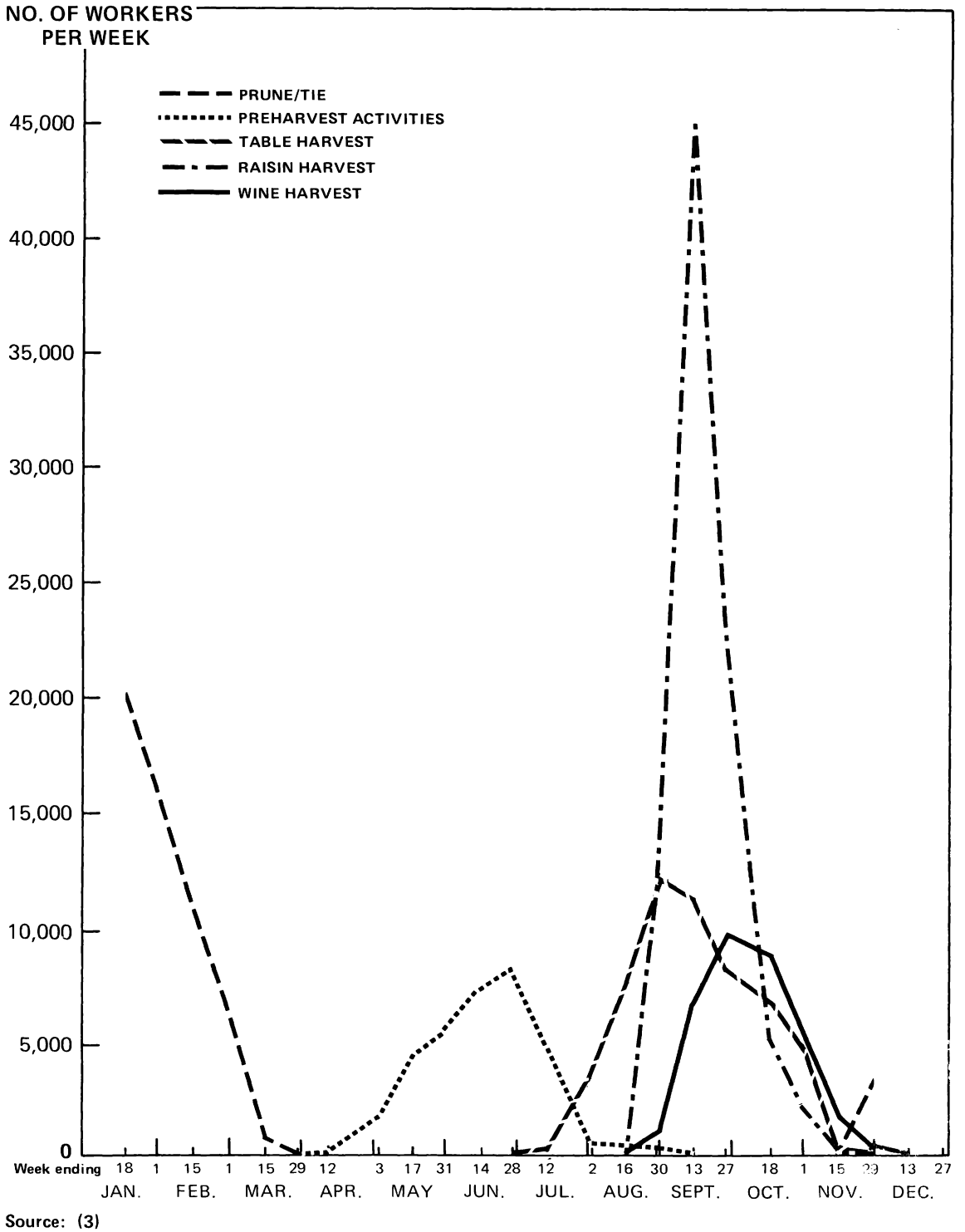
Figure 1 shows labor use for all grape production in the southern San Joaquin Valley in 1975. The wine, raisin, and table grape industries are interrelated in that such activities as pruning and harvesting occur at the same time and require similar skills. In addition, 46 percent of the bearing acreage of grapes in the area were Thompson seedless in 1974, allowing alternatives for growers to market the grapes for wine, raisins, or table. The concurrent pruning times present little problem since they last so long. The harvest periods, though, require predominantly separate labor sources since the season is short. Too, at its peak, the raisin harvest requires a work force four times that for wine or table grapes.

Prior to mechanization 1968, the wine grape harvest required 123,040 weeks of labor; the raisin, 164,860; and the table grape, 170,200 (4). Therefore, labor for the wine grape harvest amounted to 27 percent of the total grape harvest employment.

1/ Agricultural economist with the Commodity Economics Division, Economic Research Service, University of Calfiornia at Davis. 2/ Underscored numbers in parentheses refer to the bibliography listed at the end of this report. 3/ Olmo, H.P., unpublished survey data.

Figure 1

Employment of Hired Farm Workers on Grapes, So. San Joaquin Valley, 1975



Source: (3)

The harvest season for grapes for the wine crush lasts from August through November. The total wine crush is a mixture of wine, raisin, and table varieties, as shown in table 1 for 1974 (3). The season for Thompson seedless, the predominant variety, extended over 18 weeks in 1974 (confined mainly to a peak of 4 weeks during which two-thirds of the Thompsons were crushed). For all varieties, the main season was 13 weeks long (although the crush didn't top 100,000 tons a week until the seventh week).

Labor needed for the wine grape harvest naturally varies with the acreage of grapes harvested and the yield of the vineyards. Figure 2 estimates the labor requirements for several years prior to (1966-68) and after the introduction of mechanization (1972, 1974-75). The estimates are in terms of the number of workers required to harvest the crop in full-week equivalents. As might be expected, more labor was required before mechanization.

Development of Mechanical Grape Harvester

Research on the mechanical grape harvester at the University of California at Davis began in 1952 (11). The first machine to be field tested operated on the cutter-bar principle, a process requiring extra labor to prune and to free and hand-position the grape clusters before harvest. Other methods were also tried, including one based on a vacuum principle.

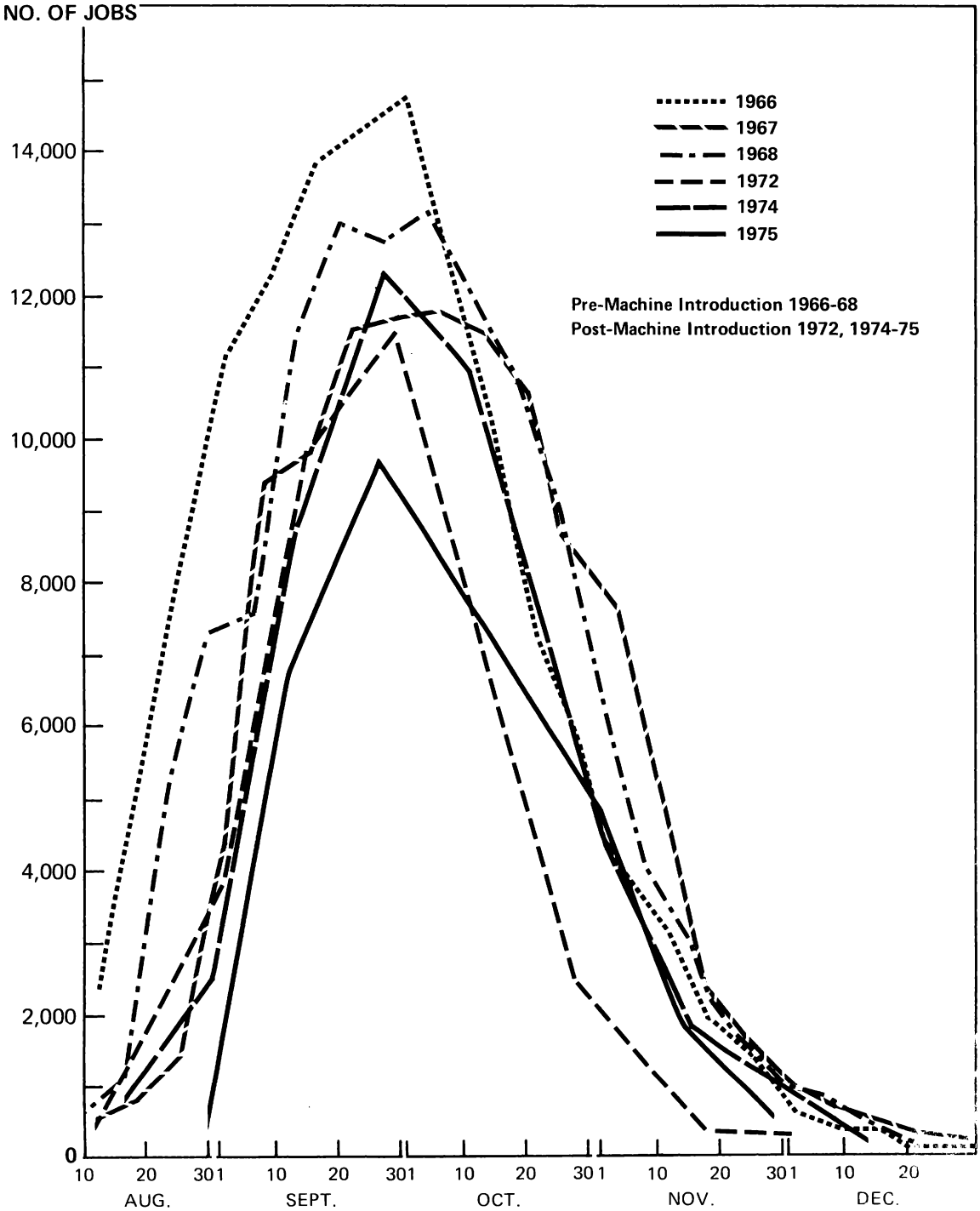
Table 1--California wine grapes crushed by type, southern San Joaquin Valley, 1974 season

1974 season	Raisin type		Table type	Wine type	Total
	Thompson	Muscat			
			Tons		
July 20	--	--	36	--	36
27	63	--	214	--	277
Aug. 3	131	--	1,537	--	1,704
10	458	--	1,748	245	2,451
17	12,309	--	3,101	3,108	18,518
25	35,404	34	3,412	9,520	48,370
31	54,173	105	209	21,948	76,435
Sept. 7	78,253	194	596	35,502	114,545
14	126,696	158	2,673	53,174	182,701
21	124,550	2,521	1,342	70,501	198,914
28	105,382	3,398	2,211	75,125	186,116
Oct. 5	59,559	5,560	7,006	72,843	144,968
12	29,237	9,958	13,919	77,012	130,126
19	8,761	11,924	27,760	53,530	101,975
26	3,434	4,575	28,495	28,310	64,814
Nov. 2	147	117	15,627	5,549	21,440
9	50	34	29,520	6,555	36,159
16	58	--	24,778	3,510	28,346
23	6	--	13,208	1,883	15,097
30	--	--	4,074	415	4,489
Dec. 7	--	--	824	--	824
14-31	3	--	761	11	775
Total crush	638,674	38,578	183,087	518,741	1,379,080

Source: (3).

Figure 2

Wine Grape Harvest Employment for Selected Years, So. San Joaquin Valley



Source: (4)

In New York, a shake-harvest system was reported in 1957, with a prototype machine developed in 1962 by a commercial company (9). Actual commercial harvest with the machine began in New York in 1967, followed shortly in Washington, with an over-the-row shake system to harvest grapes for both juice and wine. Research on the shake system adapted to wine grapes progressed also in California, and commercial harvesting began in 1969.

The machine in current use differs from its forerunners, however. It straddles the vine row, using a set of rods in a beating action to shake loose the grapes. The grapes then fall into a flexible catching mechanism, from which they are conveyed to the top of the machine and into a tractor-pulled gondola alongside. While one gondola is being filled, the other is being dumped into a truck at fieldside.

SURVEY OF HAND AND MACHINE SYSTEMS

Owners of grape harvesters and operators using hand harvesting were surveyed just before the 1973 grape harvest in the San Joaquin Valley. The study centered on Fresno and Madera Counties, where the machines were most numerous, but also included Kern, Kings, and Tulare Counties.

Thirty-four of the owners of the 103 grape harvesting machines on farms in California in 1972 were interviewed. These owners, some of whom owned more than one machine, provided data on machine harvest operation, costs and performance rates, and other information on their experience with the machines.

Also interviewed was a sample of 36 grape growers who used hand harvesting. Names for the survey were taken from an extensive mailing list of the University of California Agricultural Extension Service (now Cooperative Extension Service). The growers were chosen randomly from groupings by farm size. Some harvested grapes for raisins, but preharvest practices are the same as for wine grapes.

Characteristics of Survey Farms

The growers surveyed had little crop diversity--most grew only grapes. Farm size ranged from 16 to 251 acres, with the average being 94. The 1969 Census of Agriculture reported a predominance of small grape farms (13) in the State. Seventy-five percent of the farms had less than 100 acres of grapes, with 90 percent having 260 acres or less. The remaining 10 percent held 39 percent of the acreage.

One variety, the multipurpose Thompson seedless, constituted 85 percent of the sample acreage in 1972. In 1974, this dominant variety accounted for only 68 percent of the bearing acreage (2), and only 56 percent of the total grape acreage (3). New plantings in wine varieties are creating a shift from the regional dominance of Thompsons.

Grape yields averaged 7 tons per acre on the survey farms in 1972, compared with 8.12 tons per acre for raisin varieties in the State during 1970-74. 4/ Over the 4 years, the average of all grape yields ranged from 5.71 to 9.93 tons per acre. Such large fluctuations are not uncommon for perennial crops such as grapes.

Operating Patterns of Machine Harvesting

The grape acreage harvested by machines in the survey ranged from 0 to 600 acres per machine, as some machines did not operate in the 1972 season either because the supplies of workers were ample or yields were too low. The average acreage picked

4/ The Thompson seedless is classified as a raisin variety, and in 1974 composed 93 percent of the total raisin varieties.

by an operating machine was 237 acres, according to the 34 interviews plus additional observations of 54 machines. The 1972 harvest season began early (mid-August) and lasted until the end of October, with the average machine operating about 30 days. Winery hours determined the length of the harvester work week, with most wineries receiving grapes 5½ days per week.

Of the varieties machine harvested, 74 percent were Thompson seedless. The other 26 percent were a mixture of wine varieties (23 percent reds and 3 percent whites). The varieties vary in ease and suitability for machine harvest, with Thompson seedless among the easiest.

Machine Crew Working Hours

A majority of machine owners (80 percent) operated one shift per day. Half started about 6 a.m., and most of the others between midnight and 4 a.m., with a few running two shifts. The average shift length was over 11 hours for a single shift, and over 9 hours each for a double shift.

The average lengths of the various field operations for the single shift per operating day were as follows:

Operating time		10.3 hours
Nonoperating time		
Travel time	0.18 hour	
Eating, rest	0.38 hour	
Field repair	0.50 hour	
Light cleaning	0.33 hour	
Total nonoperating time		1.4 hours
Total shift time		11.7 hours

The few observations for two-shift operations indicated a shorter operating time and longer nonoperating time per shift.

Many owners defended operations during the cool hours of the night and early morning, claiming that cool temperatures gave easier berry separation from the vine and promoted work efficiency. Daytime proponents argued that daylight visibility was necessary for best machine operation.

Contract Operations

A fourth of the operators did some contract harvesting, especially for close neighbors or relatives. Another fourth did a lot of contracting, usually in addition to harvesting their own acreage. Of the total machine harvested acreage, 35 percent was contracted.

Custom harvest rates were not yet well established for many owners at the time of the survey. Since hand harvesting still predominated, the machine charges were often related to the going rate for hand harvesting--at the same level or slightly lower. However, many other factors could have affected the rate charged: personal relationships, the variety harvested in terms of yield and difficulty of harvest, the condition of the vineyard, the time of the year, and competition among contractors for acreage.

Harvest Machines

In 1972, a majority of the survey machines had already averaged 3 years of service. All makes of machines were considered in this study, but two manufacturers dominated. All but two of the machines were purchased new.

Other Harvest Equipment

To facilitate the transfer of grapes from the harvester to the truck, two self-dumping, 5-ton gondolas were usually purchased along with the harvester. Those who used the 1- and 2-ton gondolas designed for hand harvesting crews needed a forklift to lift the gondolas and dump the grapes into the truck. The manufacturers indicated a need for 40-50-hp tractors to pull the 5-ton gondolas, in contrast to the vineyard requirements for tractors of only 30 hp. All machine operators had to wash down the harvester frequently during the day, with a heavy cleaning at day's end. They used a large array of spraying equipment, from garden hoses up to 100- and 1,000 gallon-sprayers.

Machine Crew Characteristics

A minimum crew size was three persons--the machine operator and two tractor drivers--but in the 1972 season, the actual average was four workers. The extra man was a mechanic, or a utility worker, who stripped vines missed near row ends, where the machine has difficulty in operating, or removed trash from the conveyors.

The most important member of the crew was the machine operator. It was his responsibility to control the harvest so as to obtain the maximum quantity of fruit with the least damage. He also needed to minimize damage to vines, wires, and stakes and maintain the machine in good operating condition. Two qualities were considered essential in choosing a machine operator: a sense of responsibility and mechanical ability.

Hourly wages for hand pickers of wine grapes ranged from $1.90 to $2.00 in the region in 1972 (4). Wages for machine crews were considerably higher: Harvester operators received $2.00-5.00 per hour (typically $3.00), plus perquisites and bonuses in many cases; and tractor operators and other harvest workers received $1.75-3.25 per hour (typically $2.25), with some getting perquisites.

Operating Patterns of Hand Harvesting

Over half of the growers used a labor contractor to provide the crews for hand harvesting. For a fee, the contractor would provide and supervise the workers as well as supply harvest equipment such as gondolas, tractors, and forklifts. Operators not using contractors hired workers directly and provided their own supervision and all necessary harvest equipment. Contracting was particularly advantageous for the smaller growers.

There was some continuity of employment of crews from year to year, for growers indicated that they had the same general crew for an average of 6 to 7 years. The number of women varied between raisin and wine crews but averaged 26 percent of the crews.

Hand harvesting involves picking the grapes, putting them into hand-held containers, and then dumping the full containers into a tractor-drawn gondola. The grapes are usually severed from the vines with shears or knives, although some crews hand-strip the grapes. The filled gondolas are pulled to a loading area, where they are lifted and dumped with a forklift. Tractors and gondolas must be sufficient to keep the picking crew busy.

Crew sizes for picking wine grapes varied in the study. However, the average number of harvest workers per farm was 40, comprising 8 crews of 4 to 6 persons each. The equipment per crew consisted of a light tractor, a 1- to 2-ton gondola, and a forklift.

Attitudes Toward Mechanization

Owners of grape harvesters indicated that the machine's outstanding advantage was freeing them from many of the problems of hand harvesting, especially the worry of hiring and managing a large number of workers. Further, they felt that the machine gave them more control over the farming operation. A few also mentioned cost savings. As to features of the machine they liked least, the owners mentioned the long hours of work, machine maintenance, repair costs, the need for modification as new developments occurred, and the high initial outlay for the machine and supporting equipment. Overall, however, the owners' reactions to the machine were favorable.

Possible Damage to the Vineyard

One risk of mechanization is possible machine damage to vineyards, affecting present or future yields. Such damage includes tearing out vines, removing too many canes and spurs (which could reduce fruiting wood for the next year's crop), and defoliating (which might result in loss of vigor). Most owners in the study (75 percent) reported no damage. Some damage to vineyards was noted by 6 (19 percent), while 2 owners (6 percent) said that it was too early to tell about effects on future yields. Damage to stakes was mentioned frequently (by 8), though without much concern; judicious use of the machine they said, could avoid many of these problems. Experiments (still incompleted) indicate a potentially lower grape yield after successive years of machine harvesting, 5/ although machine owners appeared unaware of the extent of physical damage to the vines.

Problems of Winery Acceptance

Problems of winery acceptance of mechanically harvested fruit were minimal in 1972. In fact, one winery paid a slight price premium for mechanically harvested grapes. Growers claimed they delivered more grapes per ton of mechanically harvested product, noting that there were fewer stems and leaves than in hand harvested batches.

More recently, however, a major winery has discriminated against grapes harvested mechanically (5). The winery cited the problem that grapes of many varieties resisting detachment from the vine are crushed in harvest, thus permitting fermentation and oxidation to begin before arrival at the winery, potentially lowering quality. Additionally, controversy has arisen over the claim that macerated leaf matter included with mechanically harvested grapes could impart a bitter taste (6, 15).

Engineering Features

Owners had both good and bad responses to the engineering features of their grape harvesters. The best design features of the machines, according to frequency of response, were the "floating" head (movable position of the picking or "shaking" mechanism), "collector leaves" (the system of a series of overlapping leaves as a floor of the picking mechanism to contain the berries and juice), and the hydrostatic drive. Design difficulties the respondents cited were the conveyor belts, the cleaning system, the beater rods, and the catching system. It should be noted that with each model year, more improvements were introduced in the machines.

Plans for Future Machine Purchases

Of 33 respondents, 21 were planning to buy an additional harvester or to trade their present machine in on a new model within 5 years. The reasons given were to obtain an updated machine, to provide more harvest capacity for expanding acreage, and to eliminate more hand work. The six owners not wanting new machines considered their

5/ Olmo, H.P. Private communication.

present ones adequate for their acreage. Six respondents were undecided about future purchases.

COSTS AND RETURNS BY SIZE OF FARM

Assumptions

To study the effects of mechanization on financial return to growers, certain assumptions were made about such factors as farm size, varieties planted, nonbearing acreage, crops other than grapes, and vine age. The sample survey data on production activities provided the basis for the characteristics of theoretical representative farms, although regional data were used whenever available. Costs were all on a 1975 basis.

The study assumes the farms to be located in the San Joaquin Valley, with 40, 80, 160, and 240 acres, producing only grapes. The acreage harvested by machine averaged 237 per farm, of which 35 percent was contracted. An assumption was made that all acreage was bearing and of the Thompson seedless variety. The development time of 3 nonbearing years for each acre was specified as a fixed cost and allocated over the productive life of the vines. (This procedure follows the method of the University of California Cooperative Extension Service in estimating costs of production.)

Costs were calculated at the 1970-74 average yield of raisin varieties of 8 tons per acre, and contrasted with 7-10 tons per acre -- the 7-ton yield being a short one such as in 1970 and 1972, and the 10-ton yield a good one such as in 1971 and 1973.

Assumptions on machine use followed the experience of the machine owners in the survey. Average machine output was calculated at 0.7 acre per hour of operation.

The study results should apply to other grape varieties and to other growing areas. Cultural practices for grapes are similar, so that the preharvest costs can be used either directly or adjusted from the Thompson seedless costs. The costs of machine harvesting will apply to all varieties, although adjustments will be needed for the greater machine speed in low-yielding fields.

Preharvest Variable Costs

This section presents the preharvest variable costs for grapes, common to both hand and machine harvesting. These costs include expenditures for labor, materials, gas and oil, repairs, an interest charge of 8 percent (for 6 months) on production expenses, and general expenses (table 2). The general expenses were adapted from the University of California Cooperative Extension cost estimates for Thompson seedless (14). In total, preharvest variable costs were $246.43 per acre.

Machine Harvesting Variable Costs

Variable costs for machine harvesting are the costs incurred only when equipment is in operation: fuel, repair costs of the machine, and labor (table 3). Equipment use, based on 1972 costs, totaled $37.58 per hour. With the machine performance rate of 0.7 acre per hour, the variable cost was $53.74 per acre. Adding on contract hauling of 8 tons at $4.00 per ton gives a variable cost of harvest of $85.74 per acre. This study does not consider periodic modification or update costs, including possible machine innovations, as typical of the earlier years of grape harvester development. An average modification cost in 1972 for machines having operated 3 or 4 seasons was $2,271.

Table 2--Variable costs per acre of producing Thompson seedless grapes, southern San Joaquin Valley, for hand and machine harvesting at a yield of 8 tons per acre.

Activity and item	Equipment		Materials cost	Labor		Interest @ 8% for 6 months	Variable costs
	Use	Cost		Amount	Cost		
	Hours	Dollars	Dollars	Hours	----- Dollars -----		
Preharvest operations:							
Pruning					38.40 5/	1.53	39.93
Brush disposal	0.6	0.78		0.6	1.59	.09	2.46
Tying					6.85 6/	.27	7.12
Sulfuring (6 X)	2.0	2.60	3.60 2/	2.0	5.30	.46	11.96
Irrigation (3-½ ac. ft.)			12.00	6.0	13.80	1.03	26.83
Nematode treatment 1/ 3/						.48	12.48
Fertilizer 1/ 4/						.28	7.28
Pest management 1/						1.40	36.40
County taxes						1.24	32.24
Repairs (not tractor)						.36	9.36
Irrigation preparation	4.0	5.20		4.0	10.60	.63	16.43
Miscellaneous labor	1.0	1.30		3.0	7.95	.37	9.62
Miscellaneous materials						.52	13.52
Business and office costs						.80	20.80
Preharvest total variable costs							246.43
Alternative harvesting and total variable costs: hand and machine systems:							
Hand harvesting -- contract (40- and 80-acre farms)							
Labor					60.00 7/		
Equipment (contract)		56.00					
Hauling (contract)		32.00					
Total contract hand harvesting variable costs per acre							148.00
Total preharvest and contract hand harvesting variable costs per acre							394.43

See footnotes at end of table. --Continued

Table 2--Variable costs per acre of producing Thompson seedless grapes, southern San Joaquin Valley, for hand and machine harvesting at a yield of 8 tons per acre, Continued

Activity and item	Equipment		Materials cost	Labor		Interest @ 8% for 6 months	Variable costs
	Use	Cost		Amount	Cost		
	Hours	Dollars	Dollars	Hours	Dollars	Dollars	
Hand harvesting -- own equipment (160- and 240-acre farms)							
Labor:							
Harvest crew				60.00 7/			
Forklift operator				4.35			
Supervisor				5.22			
Total labor				69.57			
Equipment:							
Tractors		3.28					
Forklift		1.20					
Gondolas		.34					
Total equipment		4.82					
Hauling (contract)		32.00					
Total hand harvesting variable costs per acre (own equipment)							106.39
Total preharvest and hand harvesting (own equipment) variable costs per acre							352.82

See footnotes at end of table.

--Continued

Table 2--Variable costs per acre of producing Thompson seedless grapes, southern San Joaquin Valley, for hand and machine harvesting at a yield of 8 tons per acre, Continued

Activity and item	Equipment		Materials cost	Labor		Interest @ 8% for 6 months	Variable costs
	Use	Cost		Amount	Cost		
	Hours	Dollars	Dollars	Hours	Dollars	Dollars	
Machine harvest (all farm sizes)							
Labor (4-man crew)				29.74			
Equipment:		18.12					
Grape harvester		18.12					
Tractors (2)		3.72					
Service pickup		.60					
Sprayer		.84					
Gondolas (2)		.72					
Total equipment		24.00					
Hauling (contract)		32.00					
Total machine harvesting variable costs per acre							85.74
Total preharvest and machine harvesting variable costs per acre							332.17

1/ Custom hired.
2/ 60 lbs. per acre.
3/ 34.6 lbs. active ingredients per acre.
4/ 50 lbs. N per acre.
5/ 480 vines per acre @ 8¢ per vine.
6/ $14 per 1,000 vines.
7/ 8 tons per acre @ $7.50 per ton.

Hand Harvesting Variable Costs

Hand harvesting costs are calculated by two methods: (1) for the small 40- and 80-acre farms, contract harvesting costs are used; and (2) for the 160- and 240-acre farms, costs are developed for the grower's own equipment.

The cost of contract harvesting includes the wages of the harvesters, cost of the equipment, and hauling to the winery. Wages to the crew in 1972 for harvesting Thompson seedless grapes were typically $6.50 per ton for normal yields; the equipment suppliers received $4.50 per ton; and hauling costs were $3.00 per ton. The total cost was $14.00 per ton. By 1975, the cost of the harvesting crew had risen to $7.50 per ton for Thompson seedless grapes at normal yields (4). 6/ The equipment-supply cost of $7.00 and hauling cost of $4.00 per ton brought the 1975 harvest cost to $18.50 per ton, or $148.00 per acre for an 8-ton yield (table 2). These costs are not an average of all varieties, but represent the lower costs of harvesting the variety easiest to pick (Thompson seedless), assuming a normal yield. Picking costs for other varieties and for special picking situations are arrived at independently.

Table 2 presents hand harvesting costs with the grower's own equipment. The labor costs include the piece rate of $7.50 per ton for pickers, plus the cost of supervision and forklift operation. Equipment costs include fuel and repairs for tractors, gondolas, and the forklift. Total noncontract costs of harvest, including hauling, were $106.39 per acre.

Table 3--Machine variable costs of wine grape harvesting

Item	Fuel, grease 1/	Repairs	Total variable costs	
			Per hour	Per acre 2/
		Dollars		
Equipment				
Grape harvester	1.27	11.40	12.67	18.12
40 tractors (2)	1.20	1.40	2.60	3.72
Service truck (3/4 ton)	3/ .19	.23	.42	.60
Sprayer, 300-gallon	4/ .14	.45	.59	.84
Gondolas (2)	---	.50	.50	.72
Labor 5/ (1 machine operator; 3 tractor drivers)			20.80	29.74
Total variable costs:				
Per hour			37.58	
Per acre				53.74

1/ Diesel fuel: $0.30/gal. Fuel and equipment repair from (8). Repairs on mechanical harvester computed at 60 percent of cost over the life of the machine (2,000 hours).
2/ The rate of output per machine averaged 0.7 acre per hour.
3/ Based on 5 miles per machine hour.
4/ Assumes 1 hour cleaning daily after 10 hours of operation.
5/ Assume 1 hour cleaning by two men after operation, and 1 hour of non-operating time for all travel, field repairs, light cleaning. Wages of $6.00 per hour for operator, $4.00 per hour for tractor drivers included fringe benefits, based on a 10-hour operating day.

6/ Also, private communications with growers and with the California Department of Employment Development.

Table 4--Average annual fixed costs of investment of wine grape farms, selected sizes 1/

Schedule of equipment	40 acres		80 acres		160 acres		240 acres	
	Hand	Machine	Hand	Machine	Hand	Machine	Hand	Machine
				Dollars				
Land	107.00	107.00	107.00	107.00	107.00	107.00	107.00	107.00
Vines	135.25	135.25	135.25	135.25	135.25	135.25	135.25	135.25
Irrigation system	27.50	27.50	27.50	27.50	27.50	27.50	27.50	27.50
Buildings	10.21	10.21	7.65	7.65	5.10	5.10	4.25	4.25
Wheel tractor - 30 hp	19.94 (2)	--	19.94 (2)	--	14.95 (3)	--	13.29 (4)	--
- 40 hp	--	52.20 (2)	--	26.10 (2)	--	13.05 (2)	--	8.70 (2)
Sprayer - 100-gal.	10.88	10.88	--	--	--	--	--	--
- 200-gal.	--	--	11.25	11.25	--	--	--	--
- 300-gal.	--	--	--	--	9.97	9.97	13.30 (2)	13.30 (2)
Disc - 8 ft. tandem	3.99	3.99	1.99	1.99	1.99	1.99	1.33 (2)	1.33 (2)
- 6 ft. offset	5.44	5.44	2.72	2.72	1.36	1.36	.91	.91
Springtooth - 8 ft.	3.99	3.99	1.99	1.99	1.00	1.00	1.33 (2)	1.33 (2)
Ridger	1.81	1.81	.91	.91	.45	.45	.30	.30
Flat furrower	1.09	1.09	.54	.54	.27	.27	.36 (2)	.36 (2)
Duster	3.08	3.08	1.54	1.54	.77	.77	1.03 (2)	1.03 (2)
Scraper	2.18	2.18	1.09	1.09	.54	.54	.73 (2)	.73 (2)
French plow	3.08	3.08	1.54	1.54	.77	.77	.51	.51
Fertilizer spreader	1.81	1.81	.91	.91	.45	.45	--	--
Cane cutters	--	--	.44	.44	.22	.22	.15	.15
Pickup, ½-ton	27.00	--	13.50	--	13.50 (2)	13.50 (2)	9.00 (2)	9.00 (2)
Truck, 2-ton	--	--	--	--	8.44	8.44	5.63	5.63
Brush shredder	--	--	1.81	1.81	.91	.91	.60	.60
Forklift	--	--	--	--	6.53	--	4.35	--
Harvester	--	176.43	--	88.21	--	44.11	--	29.39
Gondola, small	--	--	--	--	1.36 (5)	--	1.27 (7)	--
5-ton	--	20.40 (2)	--	10.20 (2)	--	5.10 (2)	--	3.40 (2)
Service truck	--	27.42	--	13.71	--	6.86	--	4.57
Total average fixed costs per acre	2/364.23	593.74	337.57	442.36	351.38	384.61	336.77	355.23

( ) denotes number of implements.

1/ The data are summarized from appendix tables 1-4.

2/ Item totals differ due to rounding errors.

Fixed Costs

Fixed costs are the costs incurred and allocated as expenses over a period of more than 1 year. Fixed costs continue regardless of production activities. Examples of these costs include annual depreciation expense, interest on investment in equipment, taxes on equipment, insurance, and licenses.

The schedules of equipment for each farm size were derived from the survey data and from University of California Cooperative Extension Service sources. Total investment for farms relying on hand harvesting ranged from $149,220 (for 40 acres) to $852,710 (for 240 acres). Table 4 summarizes investment costs from the more detailed tables 1-4 in the appendix. Comparable cost ranges for farms using machine harvesting were $205,320 (for 40 acres) to $873,110 (for 240 acres). Fixed costs per acre for hand harvesting ranged from $364.23 (for the 40-acre farm) to $336.77 (for the 240-acre farm). On the same sizes of farms harvesting grapes mechanically, fixed costs were 72 and 8 percent higher, respectively, at $593.74 and $355.23 per acre.

Total Costs

Table 5 and figure 3 give total, variable, and fixed production costs per acre. At a yield of 8 tons per acre, total costs per acre for the hand harvested grapes were, respectively, $758.66 and $732.00 for the 40- and 80-acre farms, and $704.20 and $689.59 for the 160- and 240-acre farms. In contrast, machine-picked grapes ranged from $925.91 to $687.40 per acre. Costs for machine harvesting were higher than for hand harvesting on all farm sizes except the largest--240 acres, where machine harvesting gained an advantage of less than $2.00 per acre.

Net Returns

Net returns to the operator's labor and management are calculated as gross sales minus production costs (table 5). Net returns vary with factors such as changes in production costs, yield per ton, and grape prices. Yields vary greatly with variety, year, and the growing conditions of the individual plantings. Grower prices have risen rapidly in the last few years, especially for wine varieties, due to inflation's impact on production costs. The average grower price of Thompson seedless grapes used for wine has gone from $40 per ton in 1968 to $54 per ton in 1970 to about $75 per ton during 1971-72 (3).

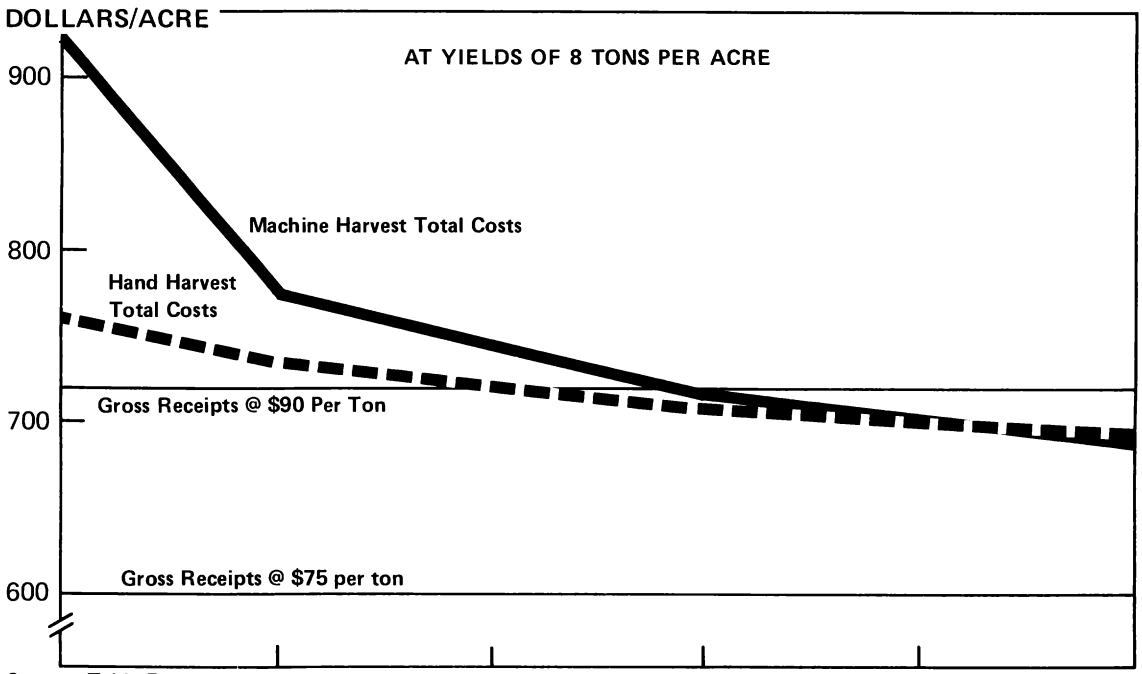
Table 5--Costs per acre of producing Thompson seedless grapes for wine: Comparison of machine and hand harvesting at a yield of 8 tons per acre, selected farm sizes

Item	40 acres	80 acres	160 acres	240 acres
	Dollars			
Hand harvesting				
Variable costs	1/ 394.43	394.43	352.82	352.82
Fixed costs	364.23	337.57	351.38	336.77
Total costs	758.66	732.00	704.20	689.59
Gross returns @ $75 per ton	600.00	600.00	600.00	600.00
Net returns	-158.66	-132.00	-104.20	-89.59
Machine harvesting				
Variable costs	332.17	332.17	332.17	332.17
Fixed costs	593.74	442.36	384.61	355.23
Total costs	925.91	774.53	716.78	687.40
Gross returns @ $75 per ton	600.00	600.00	600.00	600.00
Net returns	-325.91	-174.53	-116.78	-87.40

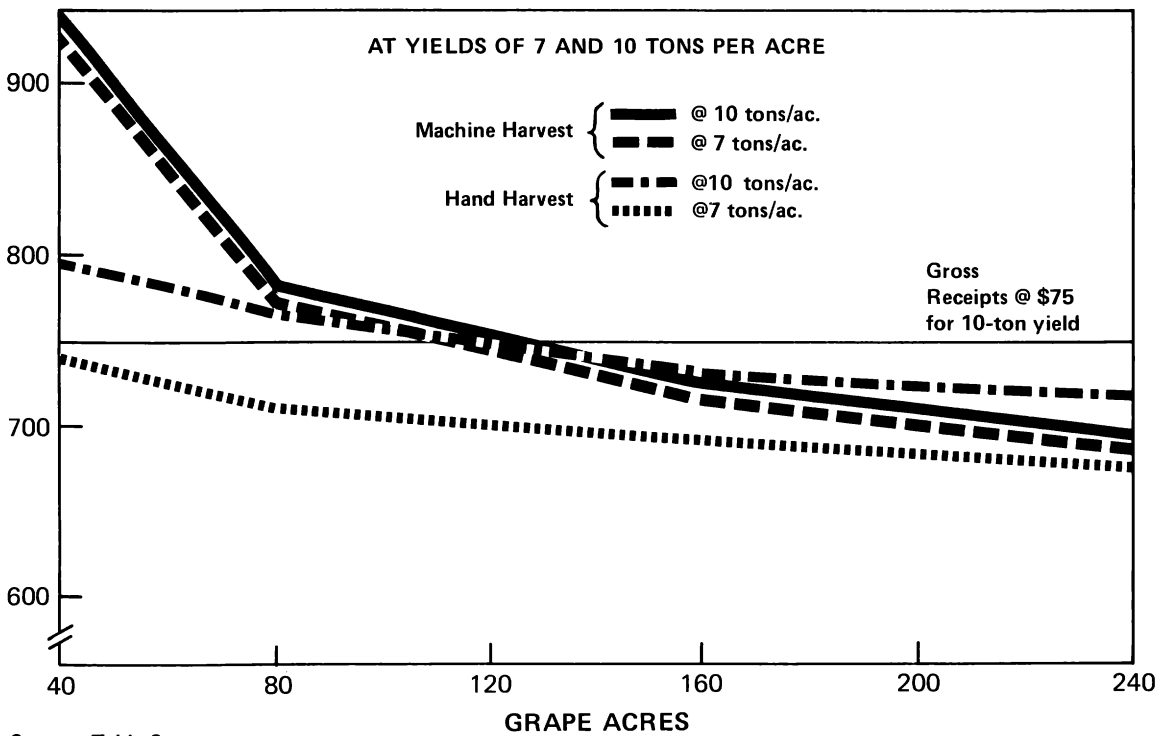
1/ See table 3 for explanation of variable cost of hand harvesting.

Figure 3

Cost of Production of Thompson Seedless Grapes for Wine, Machine and Hand Harvest, Selected Farm Sizes, So. San Joaquin Valley, 1975



Source: Table 5.



Source: Table 9.

Our comparison assumes a price of $75 per ton to growers (table 5, and figure 3). The 8-ton yield gave no farm of the sizes assumed a positve return for the operator's management and labor, although the variable costs were covered in all cases. Table 6 shows the effect on net returns of price changes of 20 percent above and below $75 per ton. At $60 per ton, no size or type of harvest brings a positive return. At $90, positive returns were calculated only for 160- and 240-acre farms.

A computation of costs per ton in table 7 provides a ready picture of the prices needed to cover costs. For all farm sizes, $49.30 per ton was required to cover variable costs. To cover total costs, $115.74 per ton was needed for the 40-acre farm using machine harvesting, ranging down to $85.92 for the 240-acre farm with machine harvesting.

A COMPARISON OF HAND AND MACHINE SYSTEMS

Break-even Acreage for Machine and Hand Harvesting

The farm size at which production costs for machine harvesting equal those for hand harvesting is the machine break-even acreage--the particular acreage for the specified set of equipment and assumptions at which the farmer would be cost indifferent to either system. The machine break-even point was reached at 220 acres at a yield of 8 tons per acre (figure 3), indicating that the machine needs to be fully utilized to achieve economies over hand systems, since the machines in the survey harvested an average of 237 acres.

Table 6--Returns per acre from wine grapes at prices 20 percent over and under $75 per ton at a yield of 8 tons per acre, selected farm sizes

Item	40 acres	80 acres	160 acres	240 acres
	Dollars			
Hand harvesting				
Gross returns @ $60 per ton	480.00	480.00	480.00	480.00
Net returns	-278.66	-252.00	-224.20	-209.59
Gross returns @ $90 per ton	720.00	720.00	720.00	720.00
Net returns	-38.66	-12.00	15.80	30.41
Machine harvesting				
Gross returns @ $60 per ton	480.00	480.00	480.00	480.00
Net returns	-445.91	-294.53	-236.78	-207.40
Gross returns @ $90 per	720.00	720.00	720.00	720.00
Net returns	-205.91	-54.53	3.22	32.60

Table 7--Costs per ton of producing Thompson seedless grapes for wine: Comparison of machine and hand harvesting at a yield of 8 tons per acre, selected farm sizes

Item	40 acres	80 acres	160 acres	240 acres
	Dollars			
Hand harvesting				
Variable costs	49.30	49.30	44.10	44.10
Fixed costs	45.53	42.20	43.92	42.10
Total costs	94.83	91.50	88.02	86.20
Machine harvesting				
Variable costs	41.52	41.52	41.52	41.52
Fixed costs	74.22	55.30	48.08	44.40
Total costs	115.74	96.82	89.60	85.92

Effect of Wage Increases on Break-even Acreage

One of the reasons for mechanizing, as given earlier, was uncertainties as to future labor costs relative to other production costs. Table 8 shows the effects of labor cost increases relative to other costs of 25 and 50 percent. At the 8-ton yield, the machine break-even acreage would be decreased from 220 to 170 acres when wages increased by 25 percent. The labor cost increase widens the cost differences of the systems in favor of the machine, because hand harvesting involves a much larger proportion of labor. At an assumed 50-percent wage increase, the break-even acreage is reduced to 143 acres. Wage increases relative to other costs significantly affect the expected break-even point.

Effect of Changes in Machine Output

The average rate of acreage harvested by the machines in the survey was 0.7 per hour, although the machine can operate faster, especially in lower yielding fields. At 1 acre per hour, the variable costs of machine harvesting were $37.58 per acre, a reduction of $17.96 per acre (21 percent of the variable cost of machine harvest). At yields of 5 tons per acre and a harvest rate of 1 acre per hour, the total cost was $637.44 per acre (or $127.48 per ton). Under the assumption that a 240-acre vineyard yielding 8 tons per acre could be harvested at 1 acre per hour, the total per acre cost would be reduced by $17.96 or 2.6 percent (table 5).

Effect of Yield Variations

Grape yields vary considerably from year to year, but expected yield is a highly significant factor in determining costs and returns of the hand and machine systems. To estimate the effect of yield changes on relative costs, yields of 7 and 10 tons per acre were assumed. The lower yield typifies raisin varieties in the State in 1972, and the 10-ton yield, those in 1971 and 1973 (3). Table 9 presents total production costs and net returns based on a price of $75 per ton calculated for the two yields, and figure 3 reveals the range in farm sizes at the machine break-even points. At 7 tons per acre, the break-even point lies beyond 240 acres, indicating that machines will need to operate at seasonal acreages greater than the survey average of 237 acres if costs are to be below those of hand harvesting. At an assumed yield of 10 tons per acre, however, the machine break-even point is 140 acres.

Table 8--Costs per acre of producing Thompson seedless grapes for wine: Comparisons of machine and hand harvesting at a yield of 8 tons per acre and at 25-percent and 50-percent wage increases, selected farm sizes

Item	40 acres	80 acres	160 acres	240 acres
		Dollars		
25-Percent wage increase				
Hand harvesting:				
Variable costs	431.40	431.40	392.18	392.18
Fixed costs	364.23	337.57	351.38	336.77
Total costs	795.63	768.97	743.46	728.95
Machine harvesting:				
Variable costs	361.58	361.58	361.58	361.58
Fixed costs	593.74	442.36	384.61	355.23
Total costs	955.32	803.94	746.19	716.81
50-percent wage increase				
Hand harvesting:				
Variable costs	468.36	468.36	431.54	431.54
Fixed costs	364.23	337.57	351.38	336.77
Total costs	832.59	805.93	782.92	768.31
Machine harvesting:				
Variable costs	390.97	390.97	390.97	390.97
Fixed costs	593.74	442.36	384.61	355.23
Total costs	984.71	833.33	775.58	746.20

The net returns of hand and machine systems at a farm price of $75 per ton ranged from all negative returns at 7 tons per acre to positive returns for the two larger farm sizes at 10 tons per acre. If the price were raised to $90 per ton, a yield of 10 tons would give positive returns for all systems except machine harvesting on a 40-acre farm.

IMPLICATIONS OF MECHANIZING THE WINE GRAPE HARVEST

Rate of Labor Displacement

As machines are introduced, hand-labor jobs are displaced and new machine positions are created. The labor displacement rate was calculated on the basis of unit labor requirements for machine and hand harvesting. For hand harvesting, worker output was 0.275 ton per hour, and 31 man-hours, including supervisory and forklift labor, were required to harvest a yield of 8 tons per acre. 7/ For machine harvesting at a rate of 1.43 machine-hours per acre, 5.96 hours per acre were needed, including crew time plus cleaning.

The ratio of machine to hand labor at an 8-ton-per-acre yield was 0.19 (5.96/31.0). For each acre machine harvested, man-hour requirements were 19 percent of those for hand harvesting, reducing the number of hand harvesting jobs by 81 percent.

7/ Unpublished estimates of the State of California, Employment Development Department.

Table 9--Costs per acre of producing Thompson seedless grapes for wine: Comparison of machine and hand harvesting yields of 7 and 10 tons per acre, selected farm sizes

Item	40 acres	80 acres	160 acres	240 acres
		Dollars		
Hand harvesting				
Yield @ 7 tons per acre:				
Variable costs	1/375.93	375.93	2/339.39	2/339.39
Fixed costs	364.23	337.57	351.38	336.77
Total costs	740.16	713.50	690.77	676.16
Gross returns @ $75 per ton	525.00	525.00	525.00	525.00
Net returns	-215.16	-188.50	-159.31	-144.70
Yield @ 10 tons per acre				
Variable costs	431.43	431.43	379.36	379.36
Fixed costs	364.23	337.57	351.38	336.77
Total costs	795.66	769.00	730.74	716.13
Gross returns @ $75 per ton	750.00	750.00	750.00	750.00
Net returns	-45.66	-19.00	19.26	33.87
Machine harvesting				
Yield @ 7 tons per acre				
Variable costs	328.17	328.17	328.17	328.17
Fixed costs	593.74	442.36	384.61	355.23
Total costs	921.91	770.53	712.78	683.40
Gross returns @ $75 per ton	525.00	525.00	525.00	525.00
Net returns	-396.91	-245.53	-187.34	-158.40
Yield @ 10 tons per acre				
Variable costs	340.17	340.17	340.17	340.17
Fixed costs	593.74	442.36	384.61	355.23
Total costs	933.91	782.53	724.78	695.49
Gross returns @ $75 per ton	750.00	750.00	750.00	750.00
Net returns	-183.91	-32.53	35.22	54.60

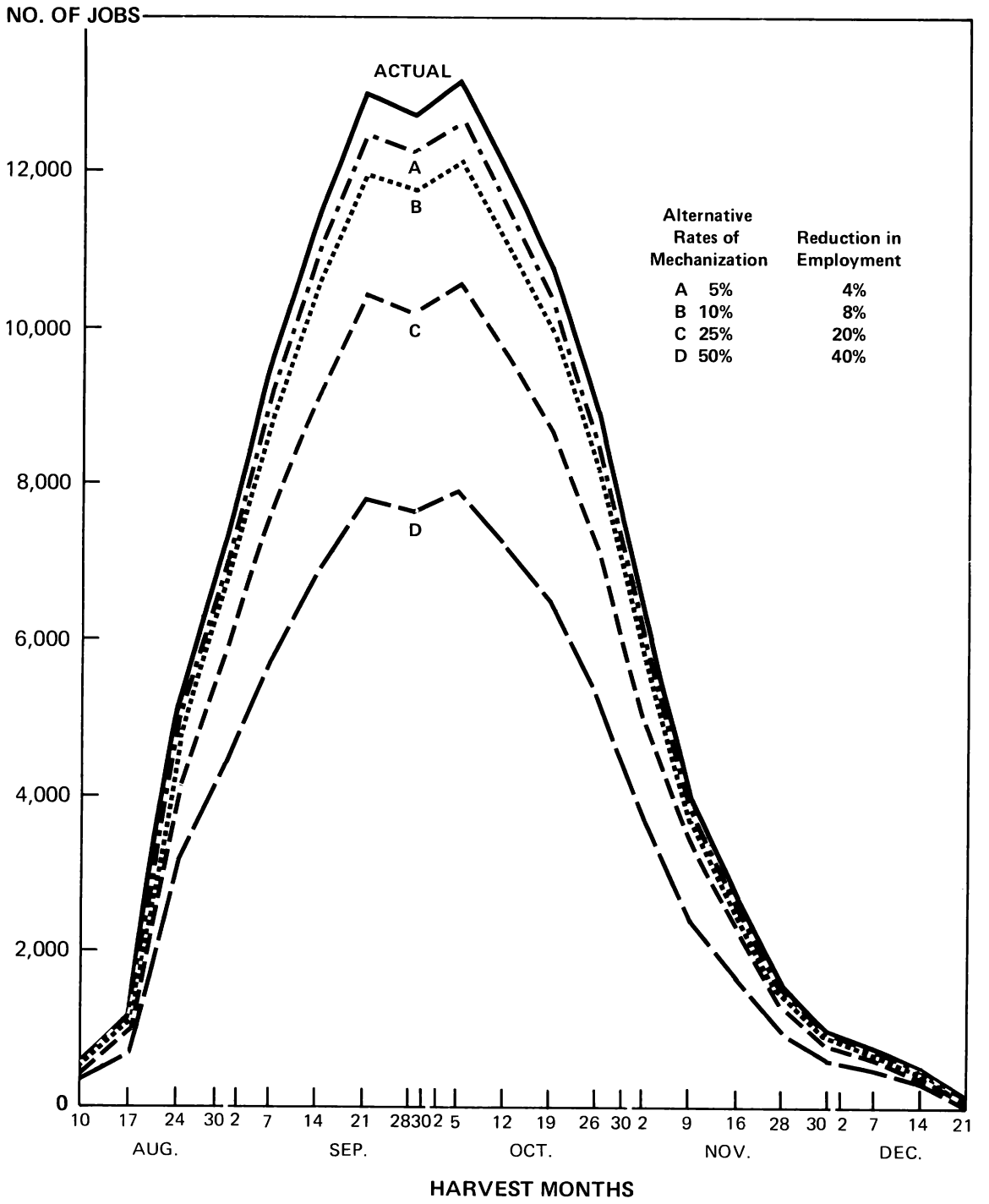
1/ At $7.50 per ton picking rate.
2/ At 160 and 240 acres, operator assumed to own hand harvesting equipment and furnishes forklift operator; at 40 and 80 acres, contract for equipment service.

Figure 4 shows the effect on employment of a range of possible machine adoption rates in the region. Wine grape employment in the pre-mechanization year of 1968 was used as a baseline. Employment estimates were in terms of equivalent full-week jobs. Over the 20-week season in 1968, employment was 123,000 man-weeks, averaging 6,150 per week. However, at 50-percent mechanization, for instance, employment decreased 40 percent, dropping by 49,200 weeks of labor.

As a conservative estimate, 5.5 percent, of California's 1974 winery crush was probably mechanically harvested. And in the southern San Joaquin Valley, the only region in the State assumed to use mechanical harvesting, was 9.2 percent of the region's total. Thus, a conservative view of present mechanization in the region falls between 5 and 10 percent of the wine grape harvest. In terms of machine displacement of labor, this amounts to a reduction in jobs of 4 to 8 percent. At 1968 employment rates, this decrease equals 246 to 492 20-week jobs.

Figure 4

Number of Full-Time Wine-Grape-Harvest Jobs per Week, 1968, With Anticipated Effects of Mechanization



Capital-Labor Substitution

Changing from hand to machine systems of grape harvesting increases capital requirements significantly. New equipment outlays are made for the harvester, larger tractors, self-dumping gondolas, service truck, and spray rig. Concurrently, there is no longer need for equipment used with hand harvesting. Therefore, the net investment is the cost of the new equipment less the hand harvesting equipment.

Due to the initial assumptions of the study, the owners of the two smaller farm sizes had no hand harvesting equipment, resulting in higher net investments than for the larger sizes of farms. The increase in investment on a 40-acre farm is $56,100, an increase of 37 percent over the capital needs for hand harvesting (appendix tables 1-4). At 80 acres, the capital requirement is increased by $50,600 (17 percent); at 160 acres, by $26,500 (4 percent); and at 240 acres, by $20,400 (2 percent).

For firms heavily in debt, the added investment requirements may prohibit machine purchase. For agriculture as a whole, the gross investment in harvesting systems for a large number of machines requires additional capital to flow into agriculture or to reduce the amount of capital available for other agricultural needs.

The amount of capital for a harvester and two gondolas ($45,200) substitutes for 1,000 hours of labor on 40-acre farms; for 2,000 hours on 80-acre farms; for 4,000 hours on 160-acre farms; and for 6,000 hours on 240-acre farms. The investment substituting for an hour of labor is $45.20 on the 40-acre farm; $22.60 on the 80-acre farm; $11.30 on the 160-acre farm; and $7.53 on the 240-acre farm.

Rate of Adoption of the Grape Harvester

Data on the percentage of the wine crush mechanically harvested, coupled with the number of machines on farms, indicate that many owners are operating their machines at substantially less than capacity. Among the factors contributing to this situation and the slow rate of mechanization in general are the following: (1) At present, the supply of hand labor is ample, and wages are near the minimum wage, so there is little immediate fear of a labor shortage or of high wages; (2) Grapes prices are currently at low levels, thus discouraging investments for such inputs as harvesters; (3) There is concern over potentially lower yields from vine damage caused by the machine; (4) Questions have arisen over product losses such as by juicing when using the machine; (5) Uncertainty exists over the question of lower wine quality from machine harvested grapes; and (6) Certain varieties are difficult to machine harvest, and may not be mechanized unless used in conjunction with expensive field crushing machinery and enclosed tanks for transportation from the field.

Due to these restraints, therefore, no rapid increase in mechanical harvesting is indicated for the immediate future. However, certain large vineyards in areas of low labor availability, which were developed during the planting boom and designed for machine harvesting, will probably be mechanized. As price conditions improve, wage rates rise, and improved machines and cultural practices are developed, mechanization will probably increase in other areas as well.

Community Welfare

A change from hand to machine harvesting means an increase in the ratio of fixed to variable costs. Therefore, growers who adopt machines are likely to be operators of larger farms, while those with small holdings usually contract machine harvesting if they use it at all. The extent to which small growers can compete with larger ones with machines may depend on the growth and competition of contract machine harvesting.

For the farmworker, the impact of the machine is fairly obvious--it could cut down significantly on his summer work. In turn, his entire employment pattern as a farmworker could be jeopardized to the extent that he would have to seek other employment. As a result, the number of farmworkers available for farm activities other than grape harvesting could decrease.

The community could also be affected. The machines can bring additional community development through the sales and servicing needed. However, the reduction in numbers of workers can disrupt the community since less income is spent for food, lodging, and other items. Also, community resources must be used if the workers require welfare aid or job retraining while in job transition. The net effect on the community is difficult to assess, though pointing to a need for additional research in this area.

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Appendix table 1--Investment and annual fixed costs, 40-acre grape farm

Item	No.	Service life	Investment	Depreciation 1/	Interest on investment 2/	Taxes & insurance 3/	Total annual fixed costs
		Years			Dollars		
Land			48,000	--	2,880.00	1,400.00	4,280.00
Vines		30	64,920	2,164.00	2,596.80	649.20	5,410.00
Irrigation system		20	11,000	550.00	440.00	110.00	1,100.00
Buildings		30	5,000	158.33	200.00	50.00	408.33
Wheel tractor, 30 hp. 4/	2	10	5,500	522.50	220.00	55.00	797.50
Sprayer, 100-gal.	1	10	3,000	285.00	120.00	30.00	435.00
Disc, 8 ft. tandem	1	10	1,100	104.50	44.00	11.00	159.50
Disc, 6 ft. offset	1	10	1,500	142.50	60.00	15.00	217.50
Springtooth, 8 ft.	1	10	1,100	104.50	44.00	11.00	159.50
Ridger (border disc)	1	10	500	47.50	20.00	5.00	72.50
Flat furrower	1	10	300	28.50	12.00	3.00	43.50
Duster	1	10	850	80.75	34.00	8.50	123.25
Scraper	1	10	600	57.00	24.00	6.00	87.00
Fertilizer spreader, 8 ft.	1	10	500	47.50	20.00	5.00	72.50
French plow	1	10	850	80.75	34.00	8.50	123.25
Pickup, 1/2-ton 4/	1	5	4,500	855.00	180.00	45.00	1,080.00
Harvester 5/	1	7	38,000	5,157.00	1,520.00	380.00	7,057.00
5-ton gondola 5/	2	15	7,200	456.00	288.00	72.00	816.00
Service truck 5/	1	8	6,500	771.87	260.00	65.00	1,096.87
Wheel tractor, 40 hp 5/	2	10	14,400	1,368.00	576.00	144.00	2,088.00
Total hand harvesting costs			149,220	5,228.33	6,928.80	2,412.20	14,569.33
Total machine harvesting costs			205,320	11,603.70	9,172.80	2,973.20	23.749.70

Hand harvesting:
Average fixed costs = $\frac{\$14,569.33}{40 \text{ acres}}$ = $364.23 per acre

Machine harvesting:
Average fixed costs = $\frac{\$23,749.70}{40 \text{ acres}}$ = $593.74 per acre

1/ Assumes salvage value of 5 percent of the original investment for all equipment. The irrigation system and vines (including stakes and trellis) are fully depreciated. 2/ Assumes interest is 8 percent of the average value of the investment, except for land, assume 6 percent. 3/ Assumes taxes and insurance are 2 percent of the average value of the investment (although included land taxes are assumed to be $35 per acre). 4/ Not used with mechanical-harvesting operation. 5/ Not used with hand-harvesting operation.

Appendix table 2--Investment and annual fixed costs, 80-acre grape farm

Item	No.	Service life	Investment	Depreciation 1/	Interest on investment 2/	Taxes & insurance 3/	Total annual fixed costs
		Years	Dollars				
Land			96,000	--	5,760.00	2,800.00	8,560.00
Vines		30	129,840	4,328.00	5,193.60	1,298.40	10,820.00
Irrigation system		20	22,000	1,100.00	880.00	220.00	2,200.00
Buildings		30	7,500	237.50	300.00	75.00	612.50
Wheel tractors, 30 hp. 4/	2	10	11,000	1,045.00	440.00	110.00	1,595.00
Sprayer, 200-gal.	1	10	6,000	600.00	240.00	60.00	900.00
Disc, 8 ft. tandem	1	10	1,100	104.50	44.00	11.00	159.50
Disc, 6 ft. offset	1	10	1,500	142.50	60.00	15.00	217.50
Springtooth, 8 ft.	1	10	1,100	104.50	44.00	11.00	159.50
Ridger	1	10	500	47.50	20.00	5.00	72.50
Flat furrower	1	10	300	28.50	12.00	3.00	43.50
Duster	1	10	850	80.75	34.00	8.50	123.25
Scraper	1	10	600	57.00	24.00	6.00	87.00
Fertilizer spreader, 8 ft.	1	10	500	47.50	20.00	5.00	72.50
French plow	1	10	850	80.75	34.00	8.50	123.25
Cane cutters	1	10	240	22.80	9.60	2.40	34.80
Pickup, 1/2-ton 4/	1	5	4,500	855.00	180.00	45.00	1,080.00
Brush shredder, 6 ft.	1	10	1,000	95.00	40.00	10.00	145.00
Harvester 5/	1	7	38,000	5,157.14	1,520.00	380.00	7,057.14
Gondola, 5-ton 5/	2	15	7,200	456.00	288.00	72.00	816.00
Service truck 5/	1	8	6,500	771.87	260.00	65.00	1,096.87
Wheel tractor, 40 hp 5/	2	10	14,400	1,368.00	576.00	144.00	2,088.00
Total hand harvesting costs			285,380	8,976.80	13,335.20	4,693.80	27,005.80
Total machine harvesting costs			335,980	14,829.81	13,839.20	5,199.80	35,388.81
Hand harvesting:							
Average fixed costs per acre = $337.57							
Machine harvesting:							
Average fixed costs per acre = $442.36							

See footnotes at bottom of appendix table 1.

Appendix table 3--Investment and annual fixed cost, 160-acre grape farm

Item	No.	Service life	Investment	Depreciation 1/	Interest on investment 2/	Taxes & insurance 3/	Total annual fixed costs
		Years	Dollars				
Land		--	192,000	--	11,520.00	5,600.00	17,120.00
Vines		30	259,680	8,656.00	10,387.20	2,596.80	21,640.00
Irrigation system		20	44,000	2,200.00	1,760.00	440.00	4,400.00
Buildings		30	10,000	316.66	400.00	100.00	816.66
Wheel tractor, 30 hp. 4/	3	10	16,500	1,567.50	660.00	165.00	2,392.50
Wheel tractor, 40 hp.	2	10	14,400	1,368.00	576.00	144.00	2,088.00
Sprayer, 300-gal.	1	10	11,000	1,045.00	440.00	110.00	1,595.00
Disc, 8 ft. tandem	2	10	2,200	209.00	88.00	22.00	319.00
Disc, 6 ft. offset	1	10	1,500	142.50	60.00	15.00	217.50
Springtooth, 8 ft.	1	10	1,100	104.50	44.00	11.00	159.50
Ridger	1	10	500	47.50	20.00	5.00	72.50
Flat furrower	1	10	300	28.50	12.00	3.00	43.50
Duster	1	10	850	80.75	34.00	8.50	123.25
Scraper	1	10	600	57.00	24.00	6.00	87.00
Fertilizer spreader, 8 ft.	1	10	500	47.50	20.00	5.00	72.50
French plow	1	10	850	80.75	34.00	8.50	123.25
Cane cutters	1	10	240	22.80	9.60	2.40	34.80
Pickup, 1/2-ton	2	5	9,000	1,710.00	360.00	90.00	2,160.00
Truck, 2-ton	1	8	8,000	950.00	320.00	80.00	1,350.00
Forklift 4,000 lbs. 4/	1	10	7,200	684.00	288.00	72.00	1,044.00
Gondolas 4/	5	10	1,500	142.50	60.00	15.00	217.50
Brush shredder	1	10	1,000	95.00	40.00	10.00	145.00
Harvester 5/	1	7	38,000	5,157.14	1,520.00	380.00	7,057.14
Gondola, 5-ton 5/	2	15	7,200	456.00	288.00	72.00	816.00
Service truck 5/	1	8	6,500	771.87	260.00	65.00	1,096.87
Total hand harvesting costs			582,920	19,557.46	27,156.80	9,509.20	56,221.46
Total machine harvesting costs			609,420	23,538.47	28,216.80	9,774.20	61,537.47
Hand harvesting:							
Average fixed costs per acre = $351.38							
Machine harvesting:							
Average fixed costs per acre = $384.61							

See footnotes at bottom of appendix table 1.

Appendix table 4--Investment and annual fixed costs, 240-acre grape farm

Item	No.	Service life	Invest-ment	Depreci-ation 1/	Interest on in-vestment 2/	Taxes & insur-ance 3/	Total annual fixed costs
		Years			Dollars		
Land		--	288,000	--	17,280.00	8,400.00	25,680.00
Vines		30	389.520	12,984.00	15,580.00	3,895.20	32,460.00
Irrigation system		20	66,000	3,300.00	2,640.00	660.00	6,600.00
Buildings		30	12,500	395.83	500.00	125.00	1,020.83
Wheel tractor, 30 hp. 4/	4	10	22,000	2,090.00	880.00	220.00	3,190.00
Wheel tractor, 40 hp.	2	10	14,000	1,368.00	576.00	144.00	2,088.00
Sprayer, 300-gal.	2	10	22,000	2,090.00	880.00	220.00	3,190.00
Disc, 8 ft. tandem	2	10	2,000	209.00	88.00	22.00	319.00
Disc, 6 ft offset	1	10	1,500	142.50	60.00	15.00	217.50
Springtooth, 8 ft.	2	10	2,200	209.00	88.00	22.00	319.00
Ridger	1	10	500	47.50	20.00	5.00	72.50
Flat furrower	2	10	600	57.00	24.00	6.00	87.00
Duster	2	10	1,700	161.50	68.00	17.00	246.50
Scraper	2	10	1,200	114.00	48.00	12.00	174.00
French plow	1	10	850	80.75	34.00	8.50	123.25
Cane cutters	1	10	240	22.80	9.60	2.40	34.80
Pickup, 1/2-ton	2	5	9,000	1,710.00	360.00	90.00	2,160.00
Truck, 2-ton	1	8	8,000	950.00	320.00	80.00	1,350.00
Forklift, 4,000 lbs. 4/	1	10	7,200	684.00	288.00	72.00	1,044.00
Gondola 5/	7	10	2,100	199.50	84.00	21.00	304.50
Brush shredder	1	10	1,000	95.00	40.00	10.00	145.00
Harvester 5/	1	7	38,000	5,157.14	1,520.00	380.00	7,054.14
Gongolas, 5-ton 5/	2	15	7,200	456.00	288.00	72.00	816.00
Service truck 5/	1	8	6,500	771.87	260.00	65.00	1,096.87
Total hand harvesting costs			852,710	26,910.38	38,867.60	14,047.10	85,254.39
Total machine harvesting costs			873,110	30,321.89	40,683.60	14,251.10	85,254.39
Hand harvesting:							
Average fixed costs per acre = $336.77							
Machine harvesting:							
Average fixed costs per acre = $355.23							

See footnotes at bottom of appendix table 1.

* U.S. GOVERNMENT PRINTING OFFICE : 1977—241-445/ERS-208